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Analysis of Factors Influencing Bagging Performance using Supervised Machine Learning Method

Ari Primantara*[1], Udi Subakti Ciptomulyono[1], Berlian Al Kindhi[1]

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Abstract: Urea fertilizer is an essential product mainly for people working in an agriculture field. The demand increases every year caused by rapidly growth globalization. This problem obliges fertilizer industry to be more competitive by reducing products losses and production cost. This study introduces supervised machine learning to predict which factors influence fertilizer weight losses during bagging process, such as moisture, products temperature, and wind pressure. Method used in this study is Random Forest Regressor, a well-known method that combines several decision trees into a single output commonly for classification and regression. Factors studied were analysed using Random Forest resulting MSE, R^2 and Spearman's method to determine the correlation between the factors towards fertilizer weight. MSE value obtained from this study was 0.0036 and R^2 -0.5334. Low R^2 result may be caused by insufficient data. The Spearman coefficients of moisture, products temperature, and wind pressure were 0.035, 0.244, 0.013, respectively. Spearman coefficient shows good result if the value ranging from -1 to +1, which obtained from products temperature. This study shows that Random Forest Regressor can predict several factors that influence productivity of fertilizer industry, particularly in bagging system. However, further research with larger data range is still needed

Keywords: *Bagging, fertilizer, industry, Random Forest Regressor*

1. Introduction

In the fertilizer industry and agricultural product trade, globalization creates new challenges for company management [1], So, in order to face global competition, it is necessary to transform industrial performance regarding competitive advantage to support company development [2]. In order to increase competitiveness in the era of global competition, companies need to make cost savings to increase efficiency [3], so, to be competitive, organizations must provide products and services at prices that are acceptable to customers [4]. In the agribusiness sector, reducing production costs is the only way to gain a competitive advantage, resulting in a production rate with an average cost that is lower than competitors and can increase the company's profitability [5].

IoT (Internet of Things) can be defined as the ability of various devices to be connected to each other and exchange data via the internet network. In general, the IoT concept is the ability to connect and/or embed hardware into various kinds of real objects so that these objects can interact with other objects, the environment or with other intelligent computing equipment via the internet network. As an IoT implementation, various Embedded System devices are used to control electronic devices with the addition of the C programming language to create programming flows that are embedded in the microcontroller so that the devices we create can run as desired.

[1] *Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
* *Corresponding Author Email: ari.petrokimia@gmail.com*

This research took place at PT Petrokimia Gresik, as part of the state-owned fertilizer holding company, PT Pupuk Indonesia. PT Petrokimia Gresik is the most complete and largest fertilizer producer in Indonesia, operating 31 factories consisting of 17 factories producing fertilizer and 14 factories producing non-fertilizer products. Fertilizer production is continuous on a large industrial scale, with products in tons and bags in large quantities. As an illustration, PT Petrokimia Gresik has 2 urea fertilizer factories (Urea I and Urea II) with a production capacity of 1,030,000 tons per year or the equivalent of 20,600,000 bags of fertilizer (50 kg packaging) per year [6]. In managing bagging facilities, there are several main problems that often occur routinely and continuously. Review of several case studies of bagging management problems in the manufacturing industry, including the problem of product spillage [7], quality of food industry bagging results [8]–[12], the problem of excessive product weight in the food industry [13], [14], variations in final weight of cement products [15] shows that the problems that often arise in bagging are the quality of the packaging and variations in the weight of the final product. Based on the evaluation of the research results in the bagging area, a sampling of the conditions of the bagging results in the fertilizer industry was carried out by referring to one of the product suitability criteria, namely the total weight of the product per package.

In the fertilizer bagging process, there are nine factors that are considered to influence the performance of the bagging machine. These factors consist of bagging machine temperature, humidity, product water content, bagging machine air pressure, product grain size, environmental dust content, gate valve setup time, product temperature, and bagging machine vibration level.

Based on the results of previous research, improving performance in the fertilizer industry and agro-industry can be done by applying supervised machine learning, as in research related to predicting the level of soil penetration resistance based on the fertilizer dose used [16] application of machine learning with the Support Vector Machine algorithm (SVM), Artificial Neural Network (ANN), Random Forest (RF), Multivariate Linear Regression (MLR) and K-Nearest Neighbour (KNN). The algorithm that can be used to predict agricultural yields with the best level of accuracy (95%) is using the RF algorithm [17]. The application of supervised machine learning to fertilizer storage management can be done by creating a prediction calculation model for air temperature [18]. In this research, the Random Forest algorithm will be used to determine corrective steps regarding factors that influence bagging as a reference for the fertilizer industry.

2. Methodology

2.1. System components and design

Components used in this study were Node MCU that consist microcontroller ESP8266 system, from Espressif System, NodeMCU can be considered as the ESP8266 Arduino board (Fig 1).

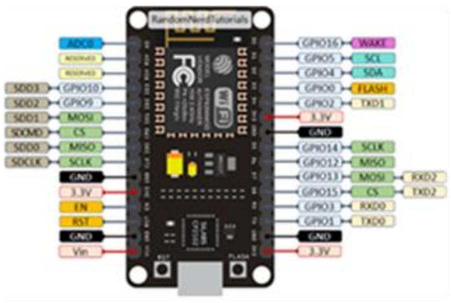

Fig. 1. Node MCU ESP8266 GPIO

A thermocouple is a type of temperature sensor that is used to detect or measure temperature through two different types of metal conductors which are combined at both ends to create a "thermo-electric" effect. The MAX6675, shown in Fig 2., is formed from cold-junction compensation whose output is digitized from the K-type thermocouple signal. The output data has 12-bit resolution and supports general microcontroller SPI communication.

Fig. 2. Thermocouple K-Type and Module MAX6675

The MPX5700 sensor is an advanced monolithic silicon pressure sensor designed for a variety of applications shown in Fig 3., but in particular those applications using a microcontroller or microprocessor with A/D input.

Fig. 3. MPX5700

Vibration Sensor (SW-420) as shown in Fig. 4 is a non-directional vibration sensor with high sensitivity. This sensor works by using a metal float which will vibrate in a tube containing two electrodes when the sensor module receives a vibration/shock.

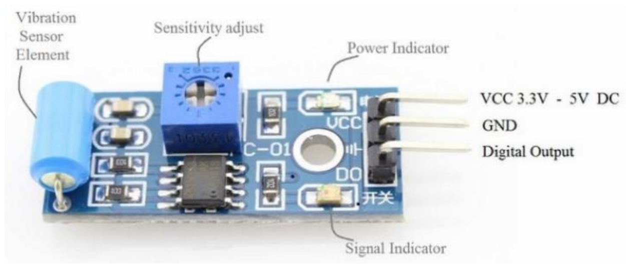

Fig. 4. Sensor SW-420

GP2Y1010AU0F Optical Dust Sensor is an infrared-based dust sensor. This sensor is very effective in detecting very fine particles such as dust or cigarette smoke, and is commonly used in air cleaning systems shown in Fig. 5.

Fig. 5. GP2Y1010AU0F

NTC, Negative Temperature Coefficient, which means the resistance of this sensor will decrease if the temperature rises and will increase if the temperature decreases. NTC sensors are usually used for temperature measurement and connected through cables to ESP8266. Sensors used were located in a bagging machine shown in Fig 7.

The data collection process is carried out during the bagging

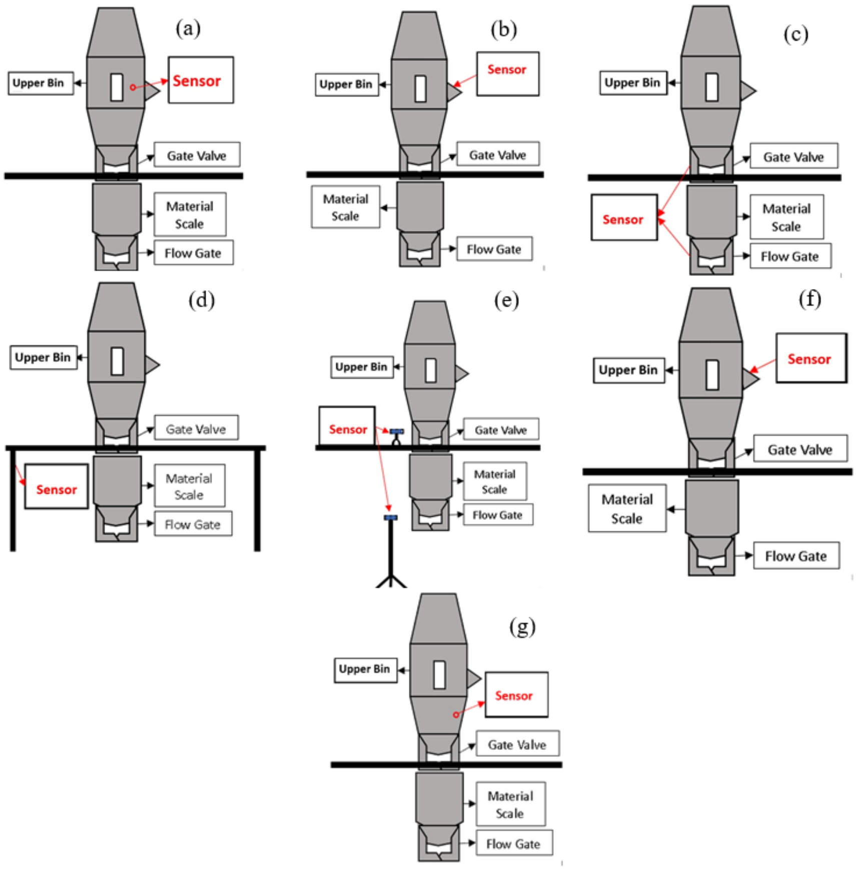

Fig. 7. Position of sensor (a) machine temperature & humidity, (b) moisture, (c) wind pressure, (d) dust, (e) setup time gate valve, (f) product temperature, (g) vibration

control of household air conditioners, car air conditioners, 3D printers, and engine temperatures. This sensor can be used at temperatures of -55˚C to 125˚C with a resistance of 10KΩ. This sensor has a waterproof feature which makes this sensor waterproof and tough in humid conditions [19].

Fig. 6. Negative Temperature Coefficient

Products temperature sensor placed in the upper bin, water content sensor located in the part that is in direct contact with the fertilizer, and wind pressure sensor placed on the piston hose. The system was built using Internet of Things (IoT) concept. Microcontroller ESP8266 acts as the program executor and gateway to internet. All sensors

process simultaneously. The data collection process starts when the fertilizer is in the upper bin. When the fertilizer is in that position, data collection of temperature and humidity is carried out which is attached to the outside of the upper bin. In the upper bin, data on the moisture content of the product is also collected with a sensor placed in a position that allows the sensor to come into direct contact with the fertilizer. Machine vibration data was also collected from sensors placed under the bin. After the fertilizer is in the upper bin position, the fertilizer will go down to the material

scale or flow gate. At that position, data on environmental dust levels is collected with sensors placed around the material scale area. Data is collected for the setup time of the gate valve which is placed in front of the gate valve. This sensor will measure the open and closed time of the gate valve. Data collection of environmental dust levels is carried out with sensors placed around the material scale area. When the fertilizer going down for bagging, data is collected for the setup time of the gate valve which is placed in front of the gate valve. This sensor will measure the open and closed time of the gate valve. Engine wind pressure is needed so that the measurement of wind pressure from the piston is carried out when running the valve from the gate

Table 1. Spearman correlation test result

	No	Dust	Humidity	Moisture	Fertilizer Temp.	Gate Valve	Vibration	Machine Temperature	Loadcell	Pressure	Product Size
No	1.000	-0.725	0.735	-0.529	-0.841	0.304	0.121	-0.868	-0.105	-0.548	-0,497
Dust	-0.725	1.000	-0.723	0.459	0.732	-0.336	0.002	0.718	0.231	0.377	0,356
Humidity	0.735	-0.723	1.000	-0.344	-0.600	0.351	0.229	-0.628	-0.002	-0.348	-0,307
Moisture	-0.529	0.459	-0.344	1.000	0.682	-0.144	-0.163	0.487	0.035	0.493	0,239
Fertilizer Temperature	-0.841	0.732	-0.600	0.682	1.000	-0.334	-0.223	0.800	0.244	0.541	0,409
Gate valve	0.304	-0.336	0.351	-0.144	-0.334	1.000	0.469	-0.292	-0.221	-0.076	0,126
Vibration	0.121	0.002	0.229	-0.163	-0.223	0.469	1.000	-0.010	-0.218	0.108	0,266
Machine Temperature	-0.868	0.718	-0.628	0.487	0.800	-0.292	-0.010	1.000	0.157	0.651	0,412
Loadcell	-0.105	0.230	-0.002	0.035	0.244	-0.221	-0.218	0.157	1.000	0.014	0,021
Pressure	-0.548	0.377	-0.348	0.493	0.541	-0.0756	0.108	0.651	0.014	1.000	0,171
Product size	-0.497	0.360	-0.307	0.239	0.409	0.126	0.266	0.412	0.021	0.171	1

valve. The packing is done and weighed from the weight of the product whether it meets the predetermined standards in the range of 50 - 50.4 kg. Urea fertilizer bags that have been weighed will be sampled for measurement of product grains using a mesh sieve.

2.2. System components and design

31 samples of urea fertilizer were obtained from 30 bags of fertilizer in one production process from bagging machine D at Warehouse 1A, Warehousing Department of PT Petrokimia Gresik, East Java, Indonesia. Samples collected for 8 hours 30 minutes with 5 minutes interval. Each sample weighed twice, first to find out the initial weight. After that, samples were sieved using mesh no. 6 and 8, and the detained samples in smaller sieve size were weighed to measure the difference. The weighed samples data then processed using Random Forest Regressor.

3. Results and Discussion

3.1. Spearman Test

The data that has been collected is tested for correlation between variables using the Spearman test. The Spearman test is a linearity test between variables where if there is a link in the data, the tied rank will be taken as the average. The Spearman correlation test has several advantages, such as being able to measure monotonic relationships so that it is not too limiting, strong against extreme values and differences between distributions, and can be used for data with a value of less than 30 data samples.

The Spearman correlation test has a value range of -1 to +1. Where it is assumed that the closer it is to 1, the stronger the correlation, while the closer it is to zero, the lower the correlation between two variables. If there is a negative value, it shows an inverse relationship. The opposite indicates that if a variable has a higher value, the other variable has a decreasing value. If the value is positive then it shows a unidirectional relationship. Unidirectional shows that if a variable has a high value, the other variable also has a high value.

In the data processing, the Spearman correlation test is used to determine the relationship between the dependent variable (X) and

the independent variable (Y). The dependent variable (X) is data on dust content, humidity, fertilizer temperature, gate valve, vibration, machine temperature, pressure and product grain size. Each dependent variable will be tested for correlation with the independent variable (Y), namely product weight.

Based on the results of the Spearman correlation test table in Table 1 it can be seen that fertilizer temperature has the strongest correlation value with a correlation value of 0.243994. Whereas, pressure has the weakest positive association with a value of 0.013536.

3.2. Effect of variables in real-time observation

An interview has been done with the foreman of Urea Warehouse 1A who has worked in PT Petrokimia Gresik for more than 11 years. He said that there are three variables that significantly affect the performance of the bagging machine; moisture, fertilizer temperature, and wind pressure.

The first variable is moisture content, high moisture content causes fertilizer granules to have a greater weight, which can affect the accuracy of fertilizer weight in the bagging process.

The next variable is fertilizer temperature, fertilizer temperature is affected by product temperature and ambient temperature. High fertilizer temperatures will change the form of fertilizer from granules to lumps. The third variable is air pressure which functions to regulate the opening and closing of the gate valve on the bagging machine. High wind pressure makes the gate valve opening and closing process more accurate, so that the weight of the bagged fertilizer is more accurate.

3.3. Random Forest Regressor

The dataset utilized for the model was obtained from sensors that are installed on Machine D within the Urea Warehouse 1A Warehousing department. This dataset corresponding values for the 9 variables.

3.4. MSE and R^2

The model that has been made is then tested using Mean Square Error (MSE) and $R2$ using the sklearn.metrics library. MSE is said to be better if the value is close to 0, while $R2$ is said to be good if the value is closer to 1. The results of modeling using the Random Forest Regressor show results that are not optimal or meet the value limit requirements. Where the MSE value is 0.0036 and the $R2$ value is -0.5334. Factors that affect the negative value of $R2$ are poor modeling, a small $R2$ value, too many variables, and too little data.

4. Conclusion

Based on the results of the correlation test between variables carried out using the Spearman test method, it is known that fertilizer temperature and pressure are the variables that have the most significant effect on weight. The Spearman test values for the fertilizer temperature variable are 0.243994 and 0.013536. This value shows that there is a unidirectional relationship between fertilizer temperature and pressure on fertilizer weight. However, the numbers presented are small so they are not very significant. According to the results in the field, there are 3 variables that have the most influence, namely moisture, fertilizer temperature and pressure. So, based on the variable correlation results, it was determined that the Random Forest Regressor modeling would use 3 dependent variables, namely, moisture, fertilizer temperature, and pressure. From the processed data, it can be concluded that the results of data modeling produce an MSE value of 0.0036 and a R^2 value of -0.5334. This value indicates that the data modeling is not appropriate, too many variables are used and too little data is used

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